Results from L3+C

Michael Unger

(Forschungszentrum Karlsruhe, DESY Zeuthen)

on behalf of the L3 collaboration

- Detector and performance
- Atmospheric muon spectrum
- Limit on $\bar{p}/p$ using the moon shadow
- Point source searches
- Future activities

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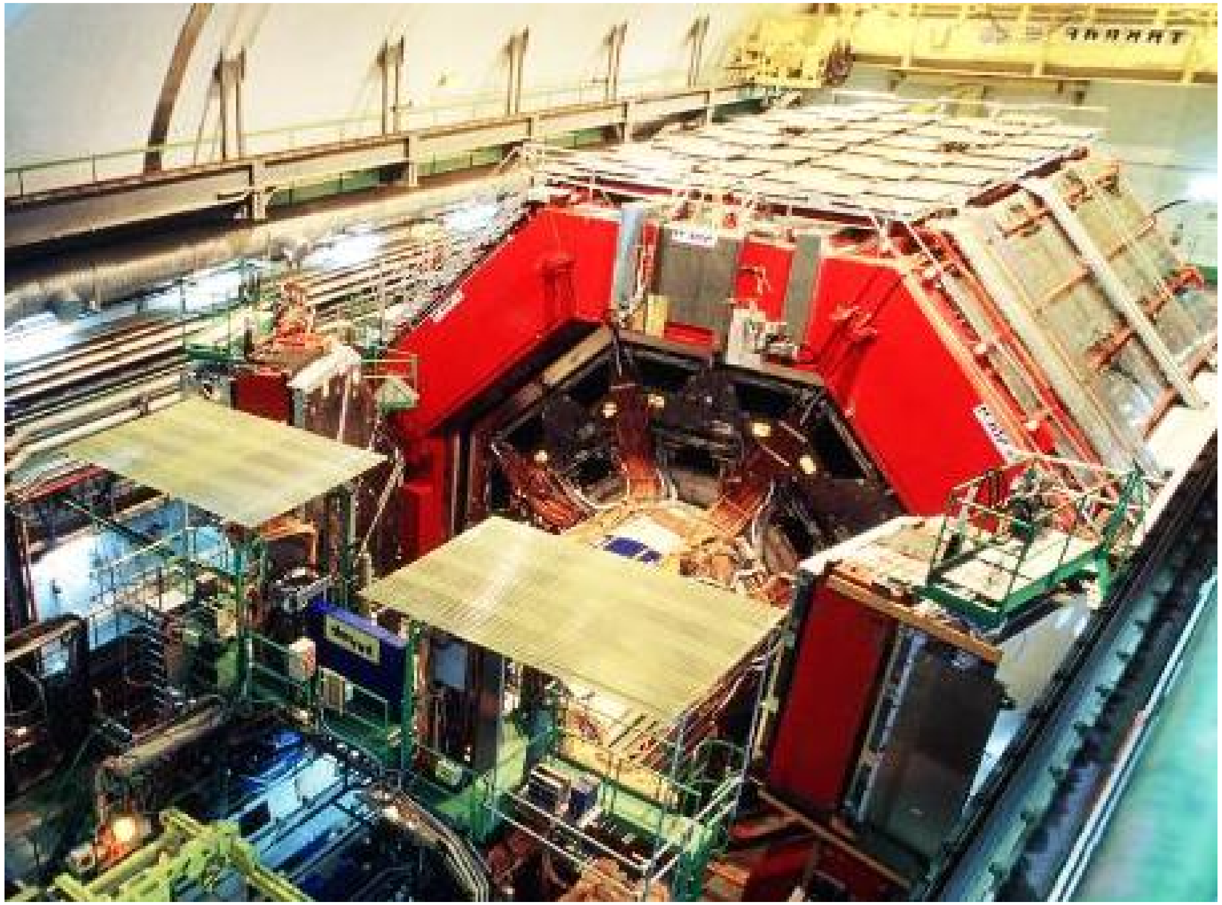
- Point source searches → Poster by P. Le Coultre
- Future activities

The L3+C Detector

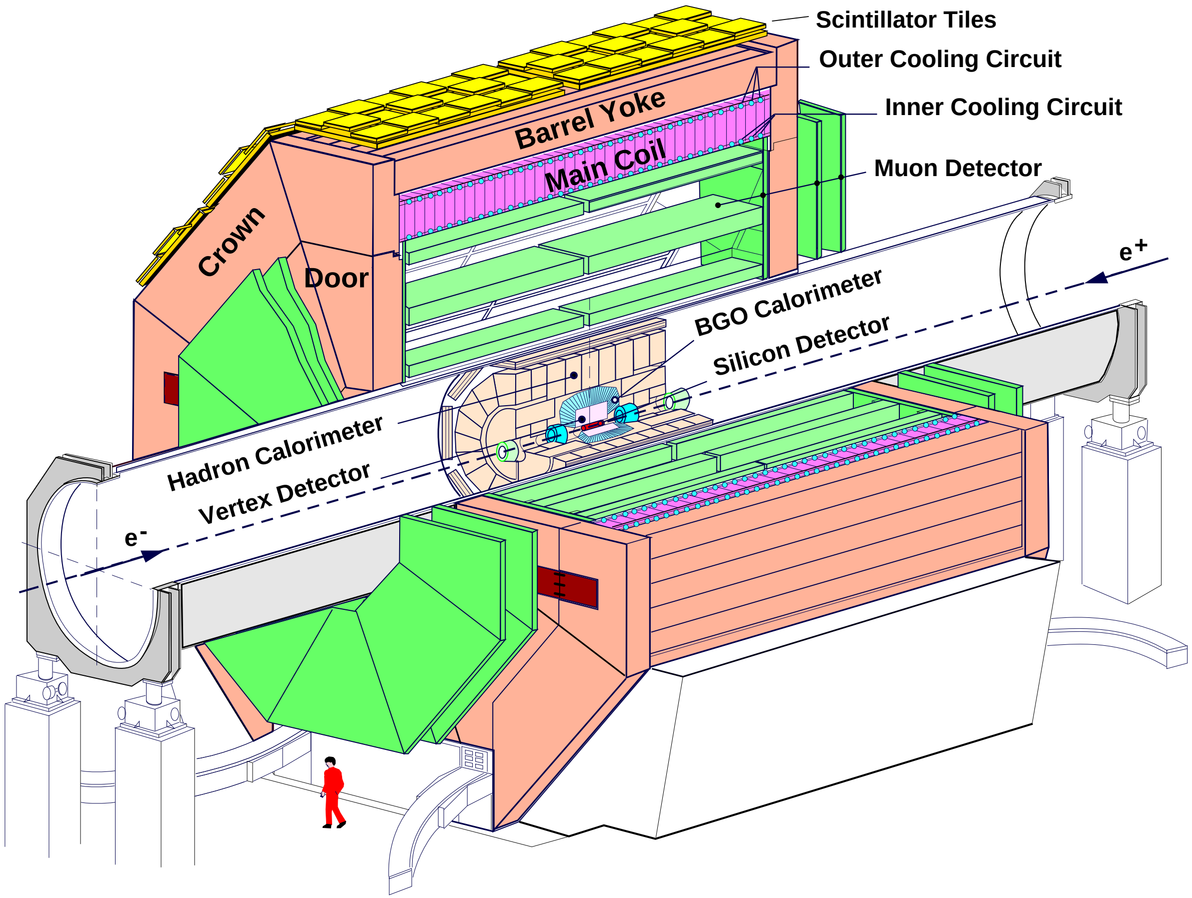
Muon Detector



- 30 m below surface
- drift chambers in $1000\ \mathrm{m}^3$ magnetic volume $(0.5\mathrm{T})$
- 202 m^2 scintillator area
- data acquisition independent from L3
- data taking in 1999 and 2000
- 12 billion muon triggers collected

The L3+C Detector

Muon Detector



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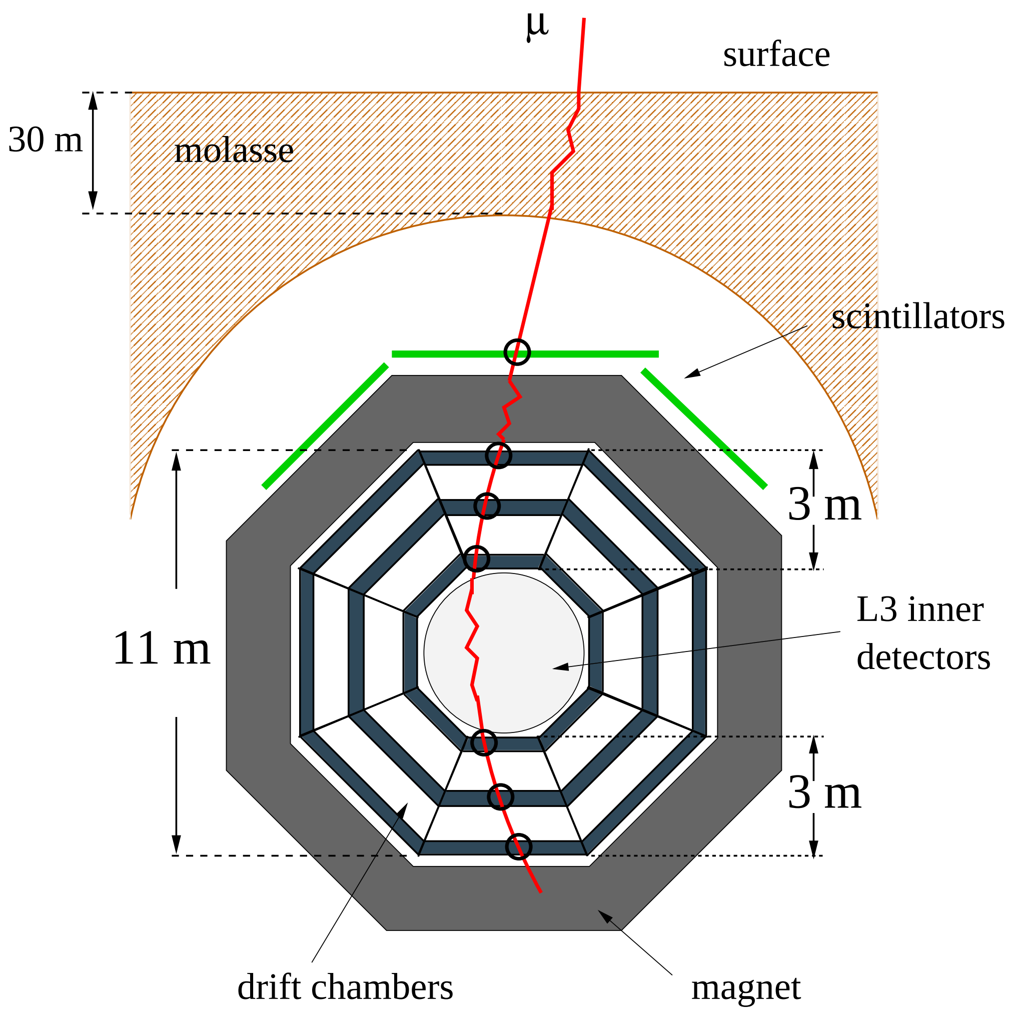
The L3+C Detector

Air Shower Detector

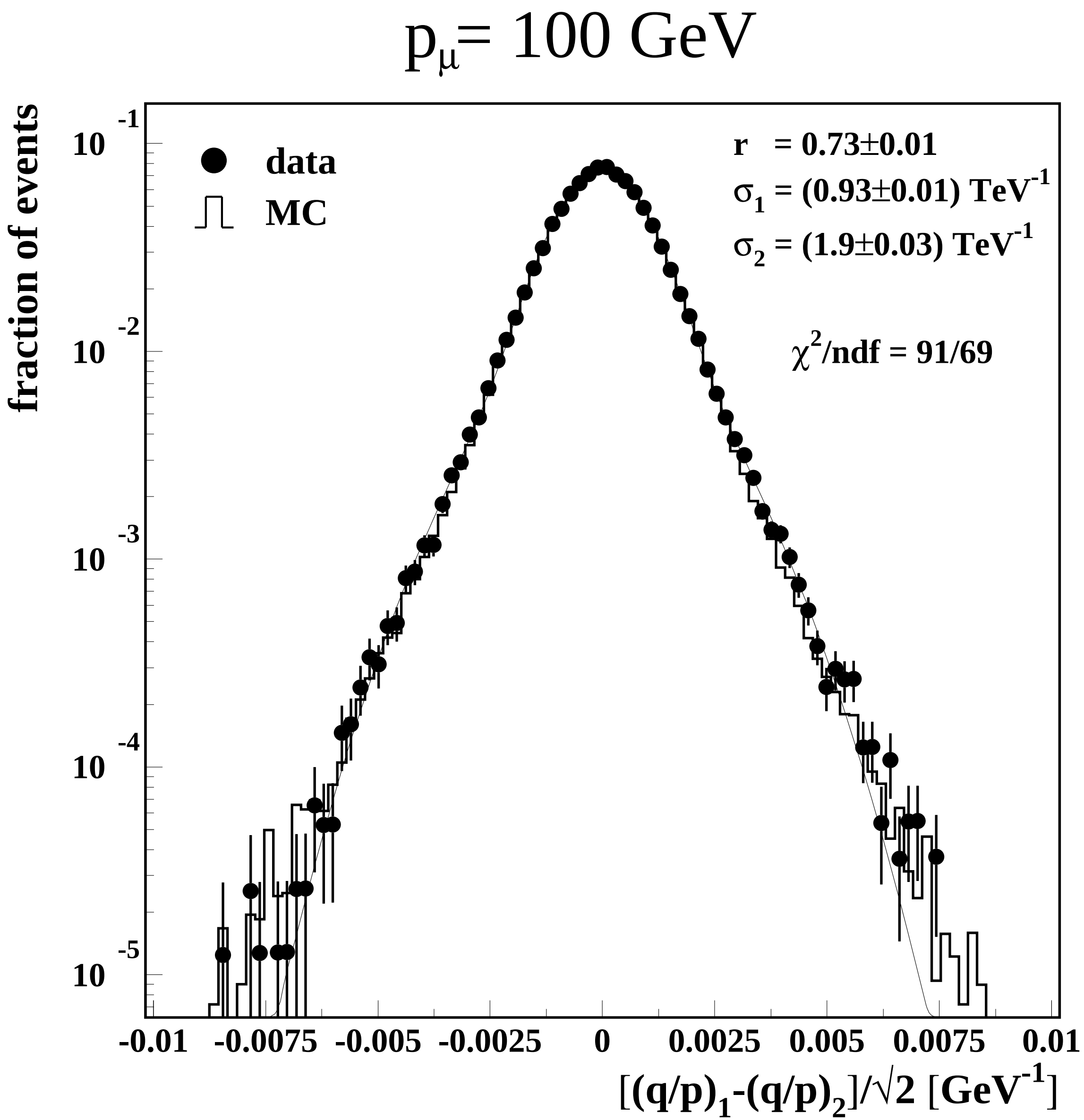
- above muon detector
- 50 scintillators ($50\times50\times1\mathrm{cm}^3$)
- area $30\times54\ \mathrm{m}^2$
- offline coincidence with muon detector
- data taking in 2000
- 27 million triggers

Momentum Measurement



- energy loss in molasse and magnet: $\langle \Delta E \rangle_{\mathrm{vertical}} = 19\ \mathrm{GeV}$
- long lever arm (11 m)
- two independent momentum measurements (3 m)

Momentum Measurement



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  $\rightarrow$adjust MC

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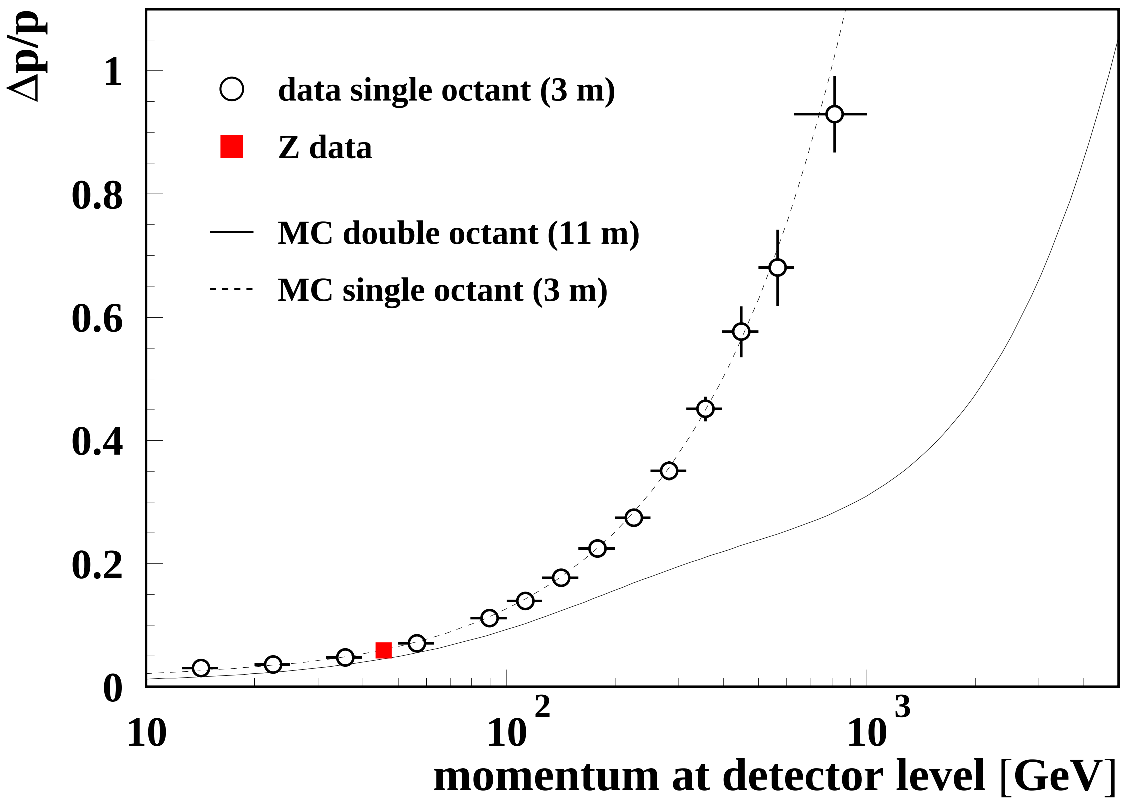

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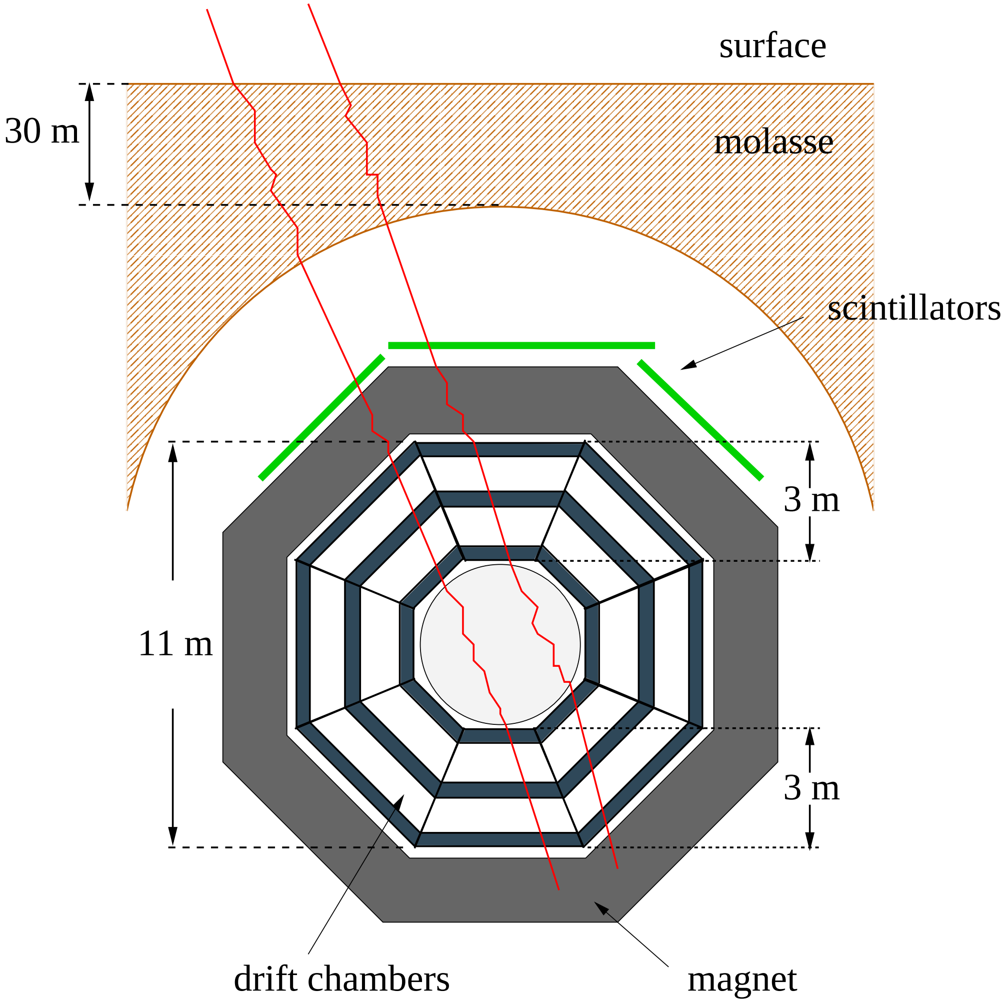
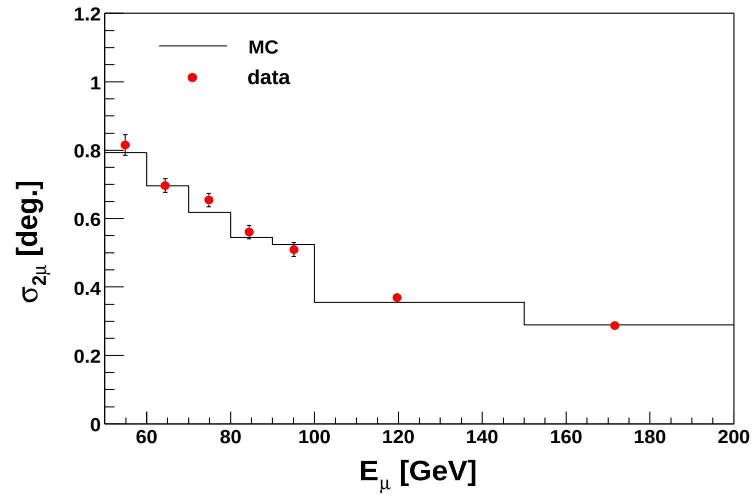
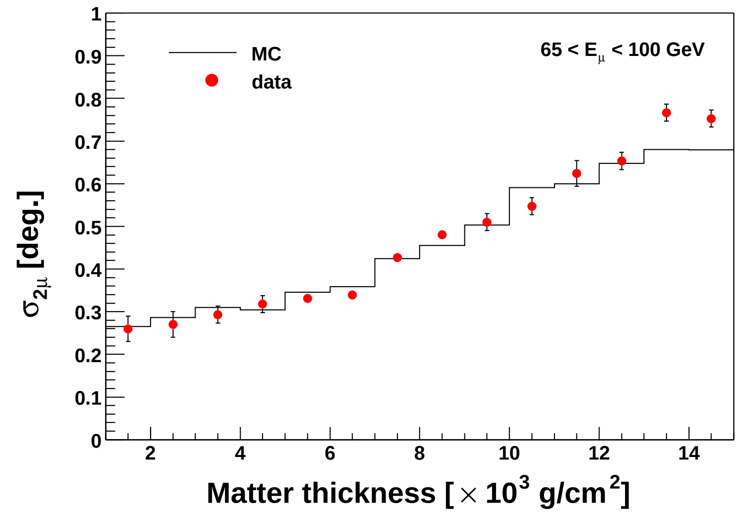
max. detectable p: 5 TeV

Angular Resolution







combined effect of:

- angle wrt. primary particle
- multiple scattering in molasse and magnet
- detector resolution

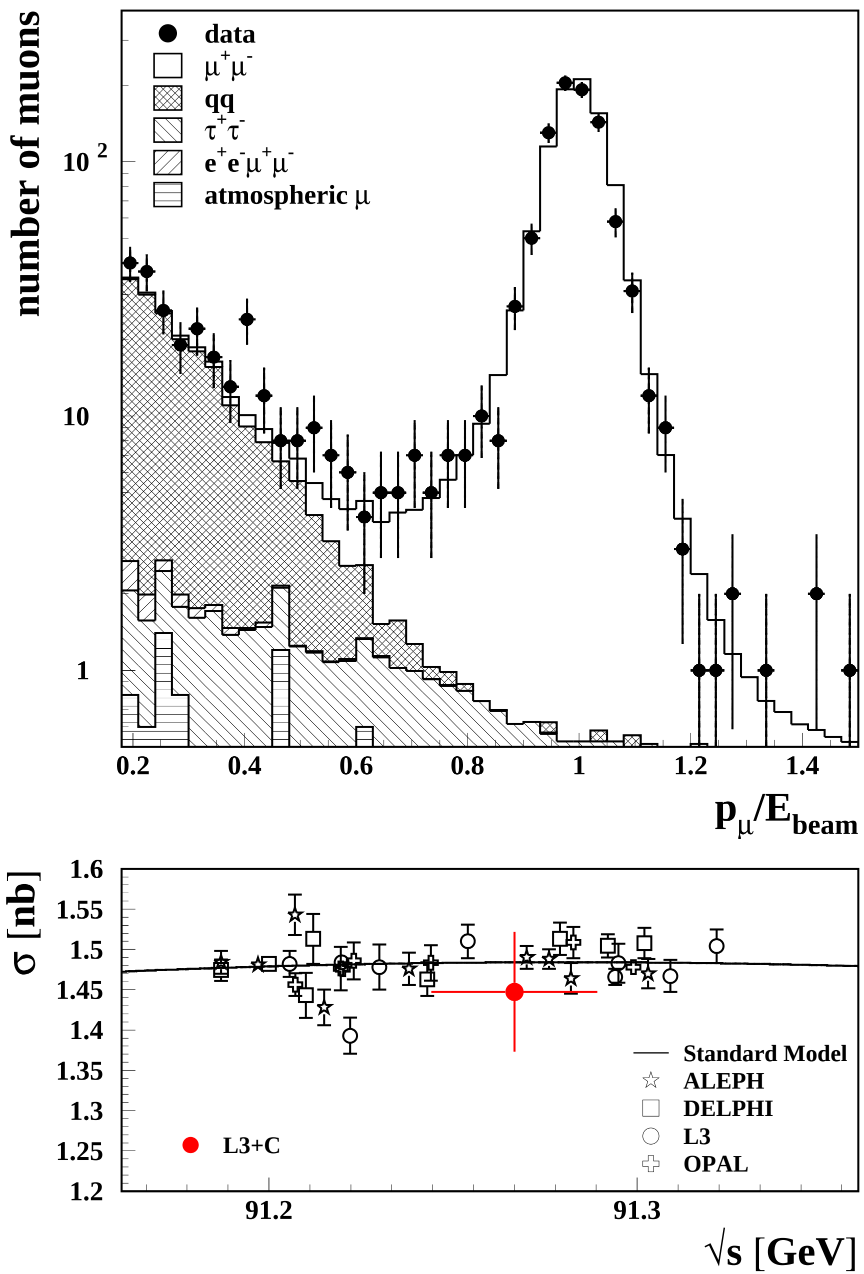
Muons from LEP

$$e^+e^- \rightarrow Z \rightarrow \mu^+\mu^-$$

- LEP calibration runs at $\sqrt{s} = M_Z = 91.2$ GeV
- 634 events selected out of $7{\cdot}10^7$ cosmic triggers

$\rightarrow$**absolute cross check of detector understanding**

Muons from LEP



- LEP calibration runs at $\sqrt{s} = M_Z = 91.2$ GeV

- 634 events selected out of $7{\cdot}10^7$ cosmic triggers

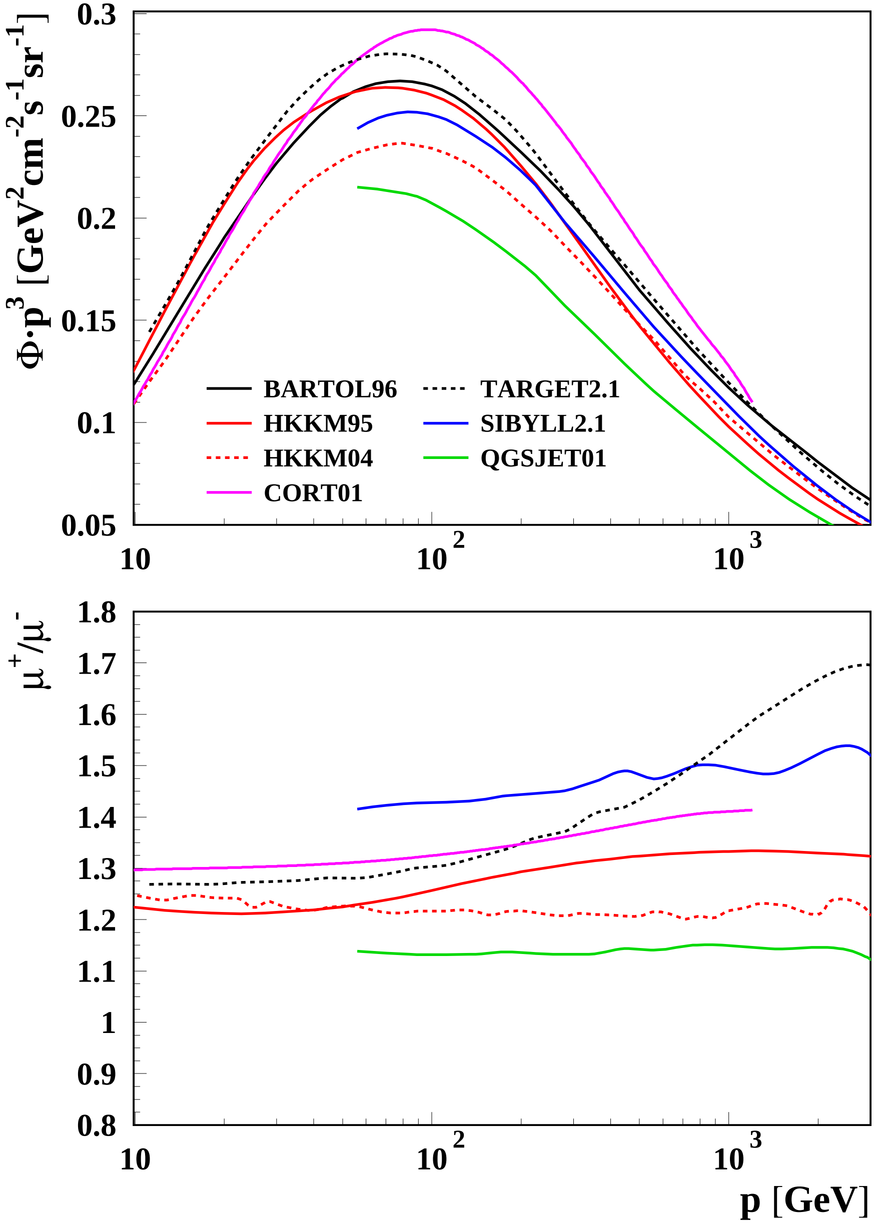
→**absolute cross check of detector understanding**

- momentum scale error: < 370 MeV

- curvature error: $< 0.1\ \mathrm{TeV}^{-1}$

- cross section agrees with LEP1 measurements

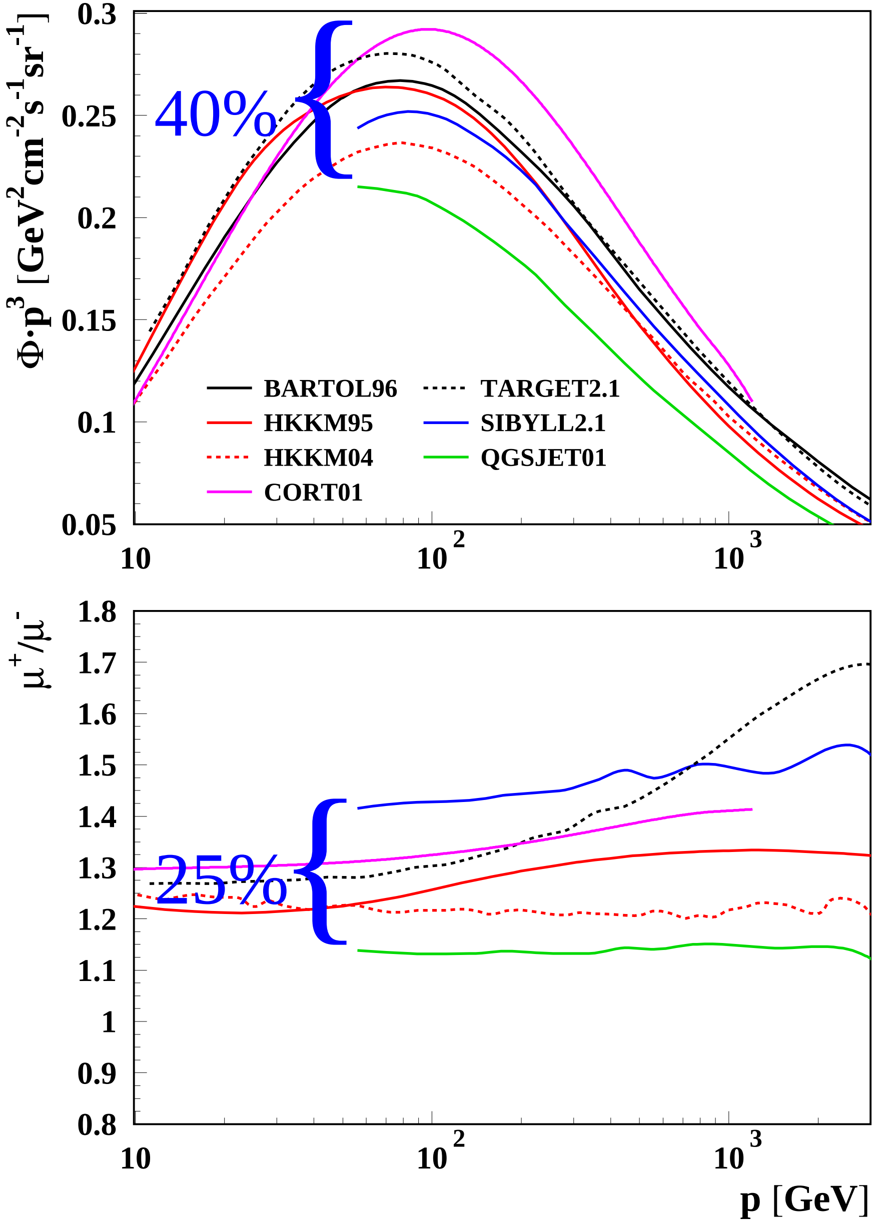
The Atmospheric Muon Flux



$$\begin{aligned}\Phi_\mu = \Phi_{\text{prim}} \quad &\otimes \quad (p + A \to \pi/K + X) \\ &\otimes \quad (\pi/K \to \mu + \nu_\mu) \\ &\times \quad [1 - P(\mu \to e + \nu_e + \nu_\mu)]\end{aligned}$$

- large uncertainties of theoretical predictions of atmospheric lepton fluxes
- muon spectrum measurement constrains $\Phi_{\text{prim}} \otimes (p + A \to \pi/K + X)$
- check of validity of neutrino flux calculations

The Atmospheric Muon Flux



$$\Phi_\mu = \Phi_{\rm prim} \otimes (p + A \rightarrow \pi/K + X)$$
$$\otimes (\pi/K \rightarrow \mu + \nu_\mu)$$
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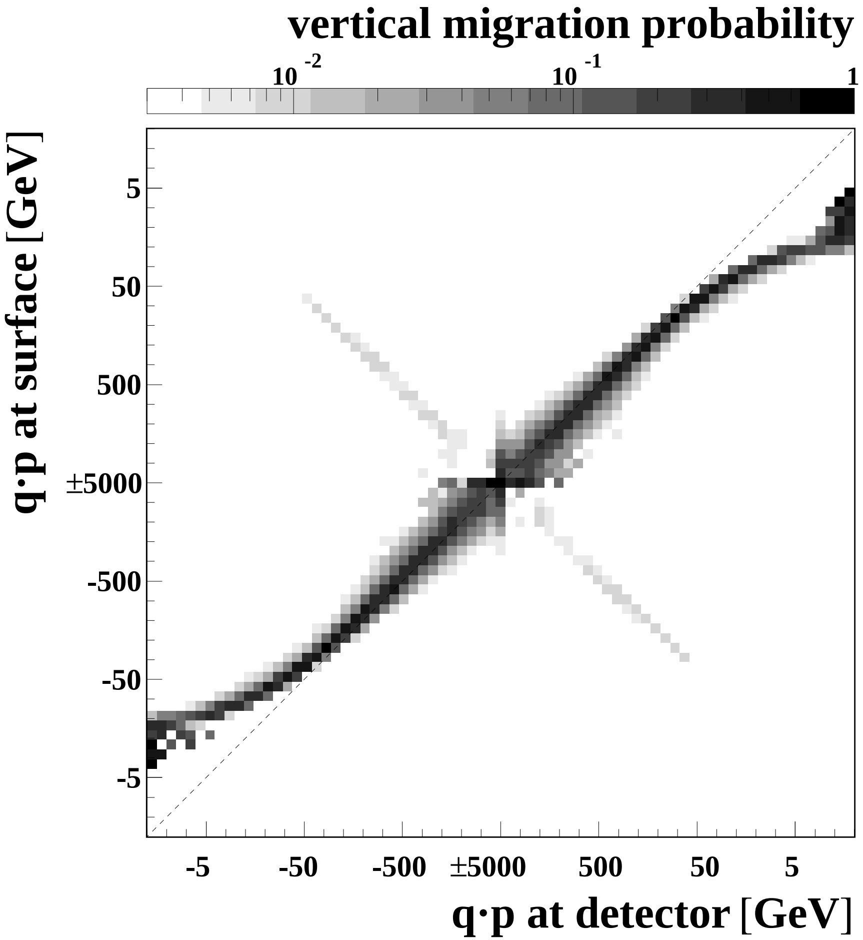
Muon Spectrum Analysis



q: charge

p: momentum

- data quality selection
  $\rightarrow$ 2.0$\cdot$ 10^7 events for spectrum analysis
- GEANT simulation of detector response and L3+C surroundings
- relation between measured event histogram $\mathbf{n}$ and surface muon flux $\mathbf{m}$:

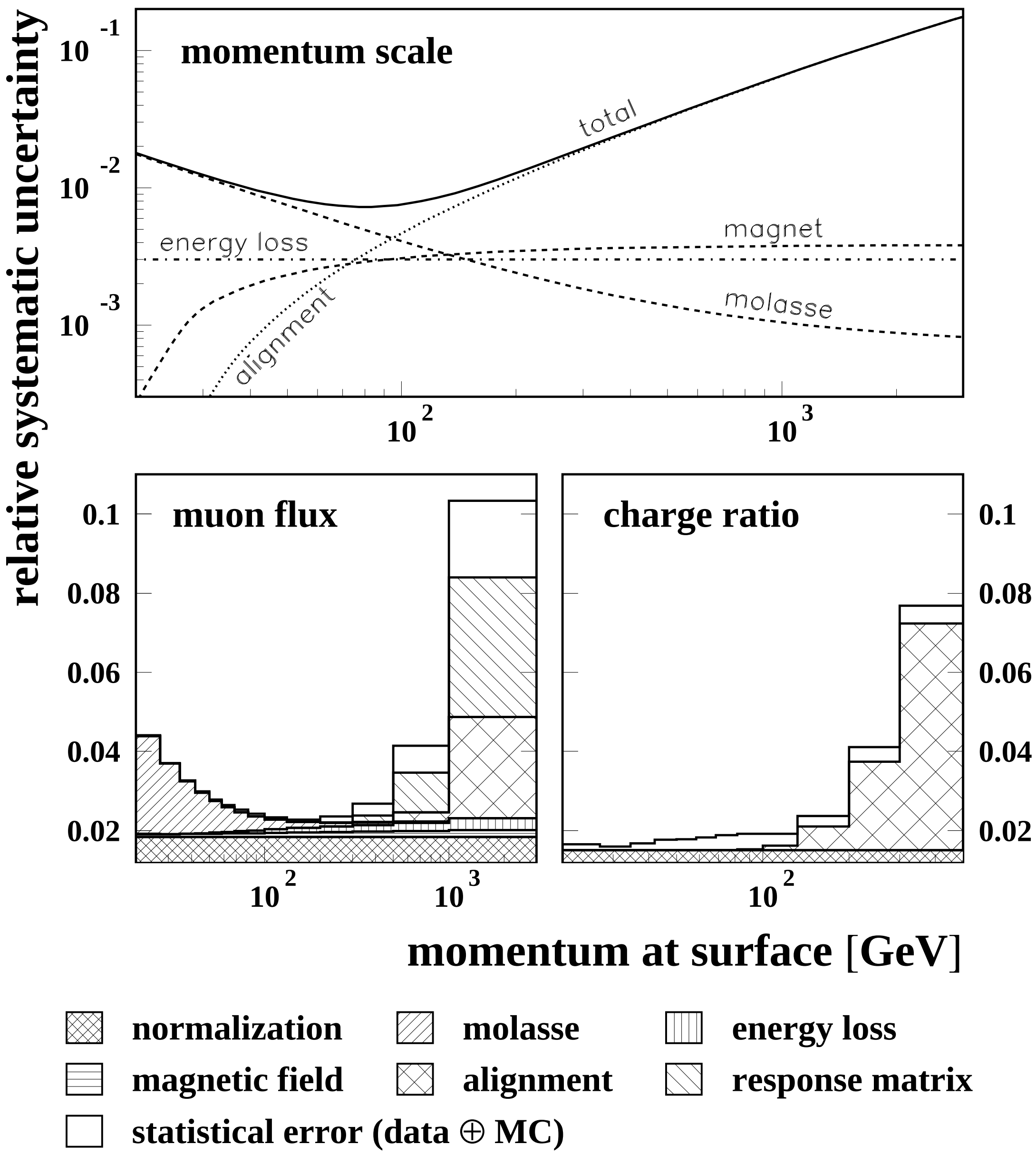
$$\mathbf{n} = \tau \cdot \mathbf{E} \cdot \mathbf{R} \cdot \mathbf{A} \cdot \mathbf{m}$$

  - τ: live-time
  - $\mathbf{E}$: efficiency matrix (diagonal)
  - $\mathbf{R}$: migration matrix
  - $\mathbf{A}$: acceptance matrix (diagonal)

- deconvolute with method of least squares

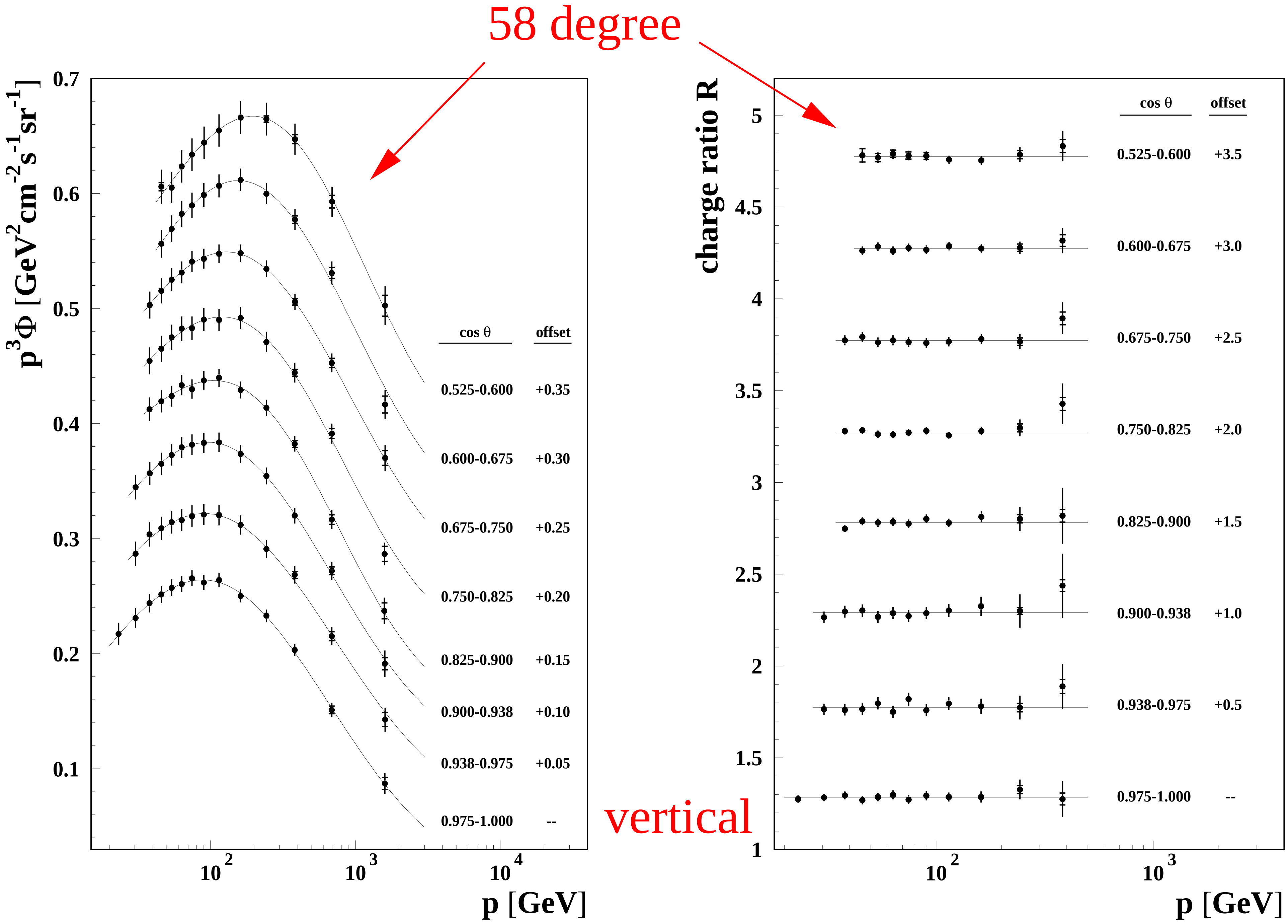
Systematic Uncertainties

(vertical direction)

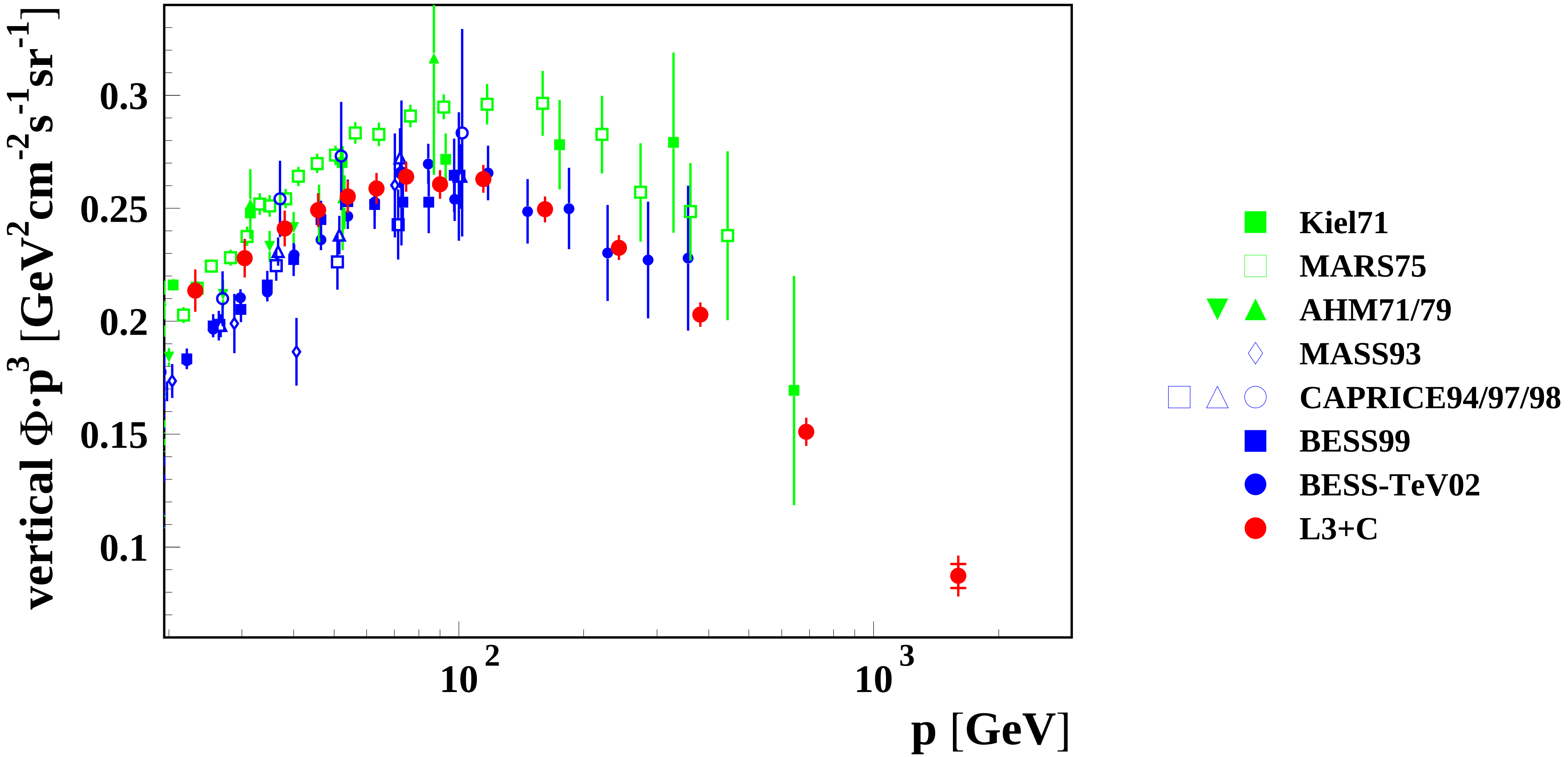


- calibration and efficiency uncertainties
- variation of selection cuts
- variation of results wrt. azimuth angle
- data subsamples

Atmospheric Muon Flux and Charge Ratio

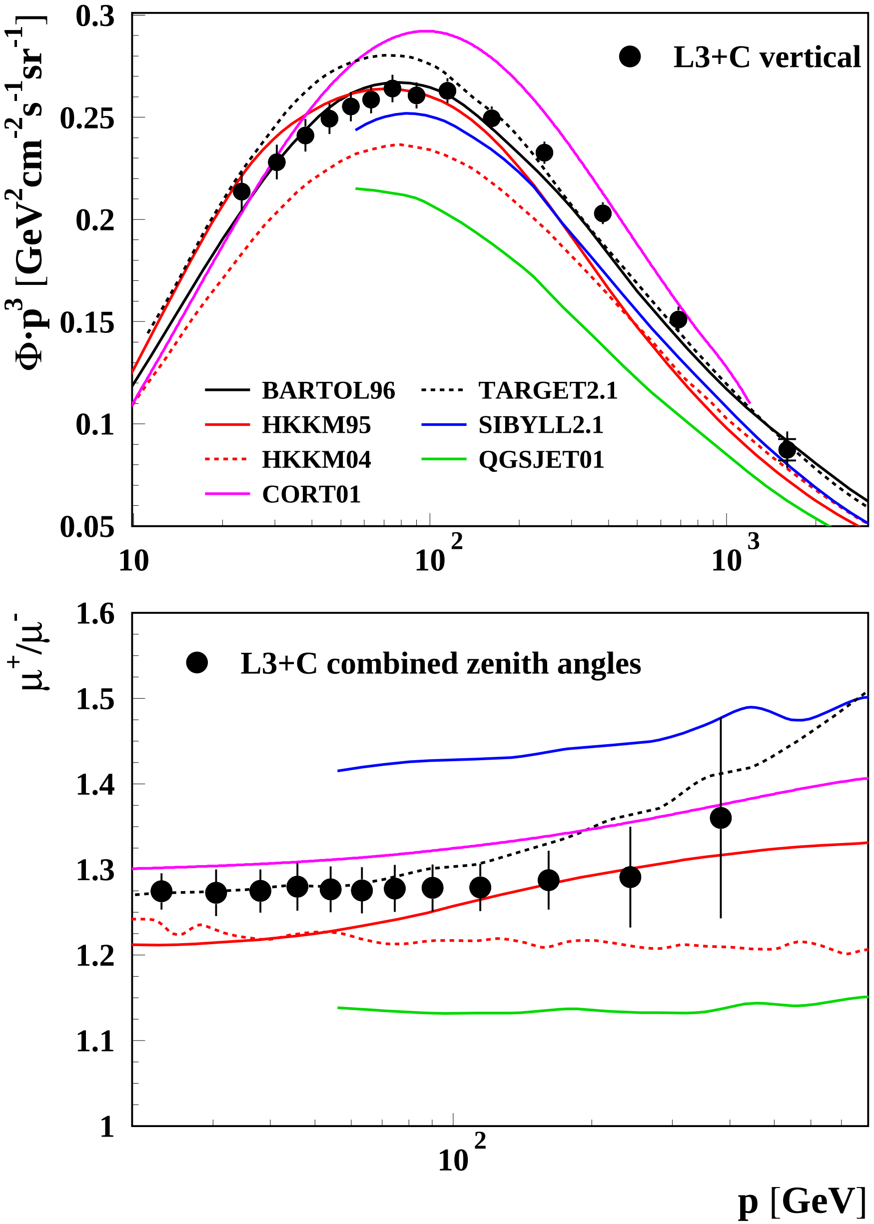


Comparison to Previous Experiments



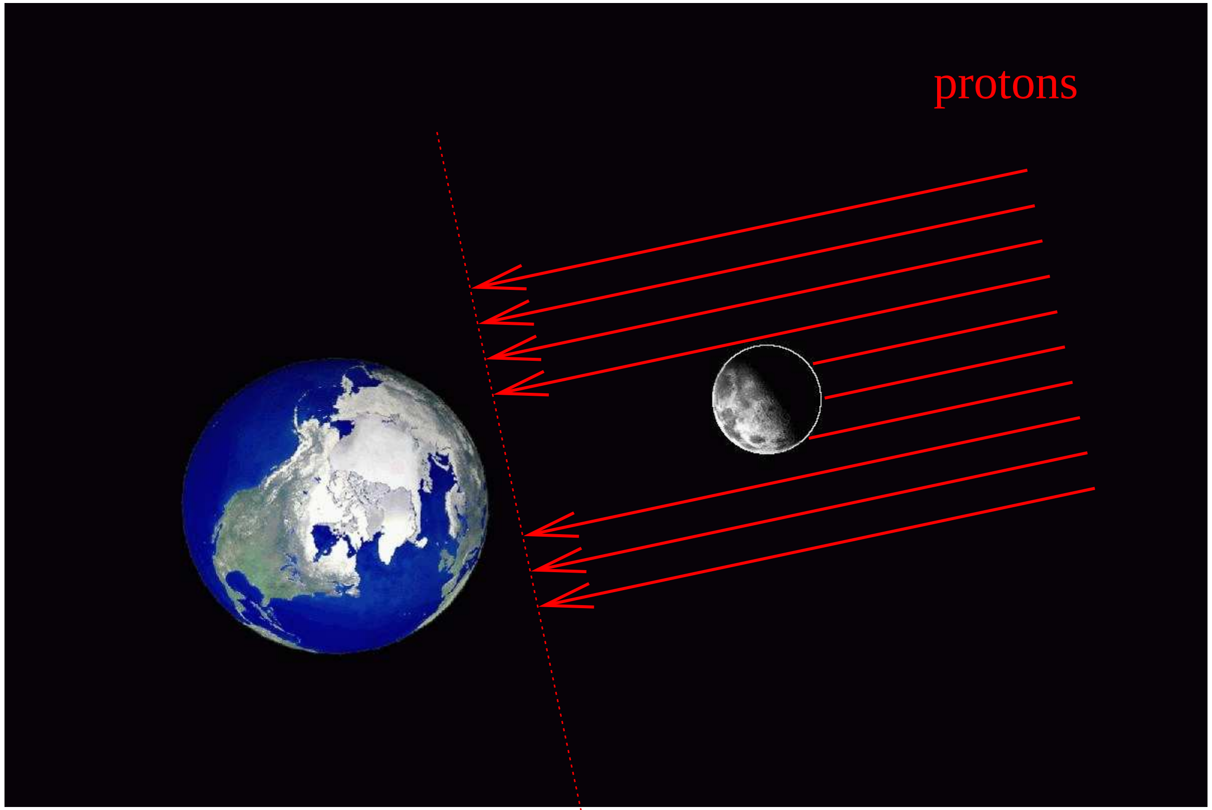
- good agreement with BESS and CAPRICE above 50 GeV
- disagreement with MARS and KIEL spectrometer data
- L3+C most precise experiment above 100 GeV

Comparison to Theoretical Predictions



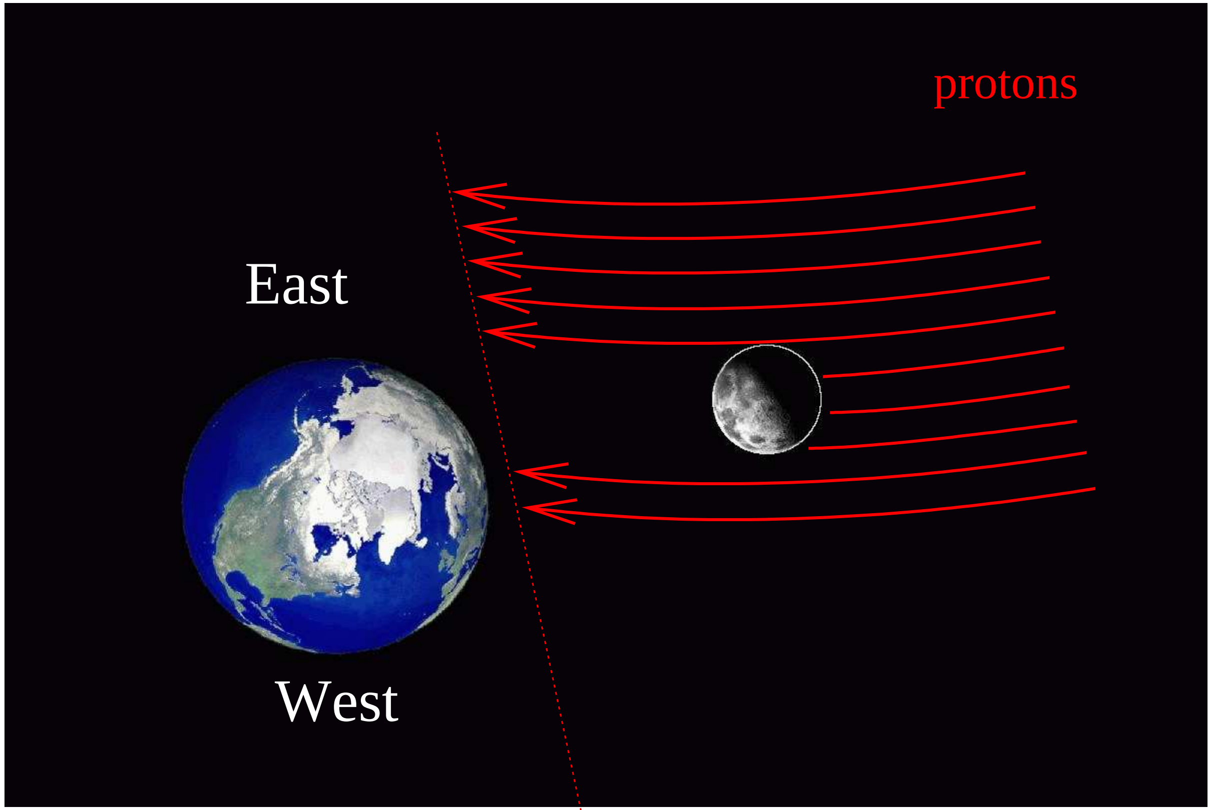
- best agreement with 'old' flux calculations HKKM95 and BARTOL95 (pre-AMS/BESS/CAPRICE primary fluxes!)
- largest discrepancy with QGSJET01$\otimes$Gaisser-Honda primary flux
- high energy rise of charge ratio can not be confirmed (systematics dominate)

Moon Shadow



- moon: absorber for prim. cosmic rays
  →moon shadow can be used for verification of exp. pointing accuracy

Moon Shadow



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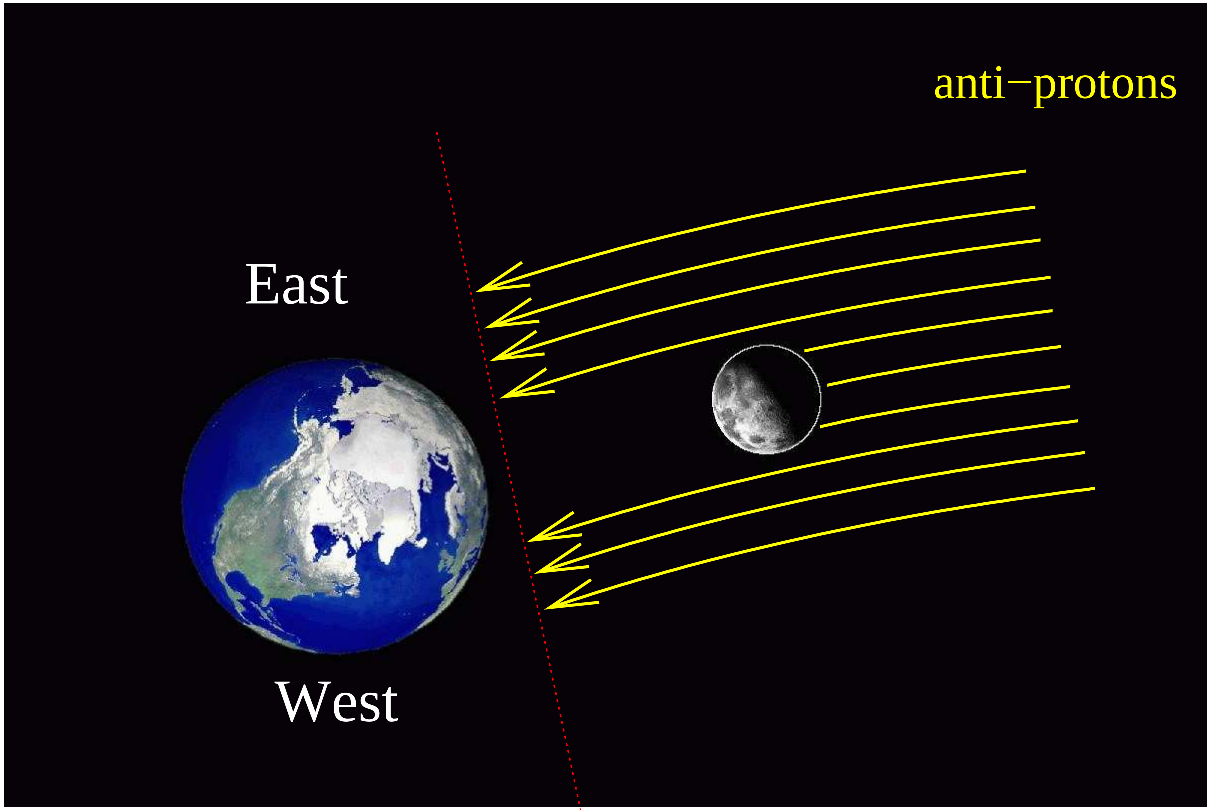
- earth magnetic field
  →shadow shifts from optical moon position eastwards

Moon Shadow



- moon: absorber for prim. cosmic rays
  →moon shadow can be used for verification of exp. pointing accuracy

- earth magnetic field
  →shadow shifts from optical moon position eastwards
  →**'anti shadow'** for anti-particles westwards

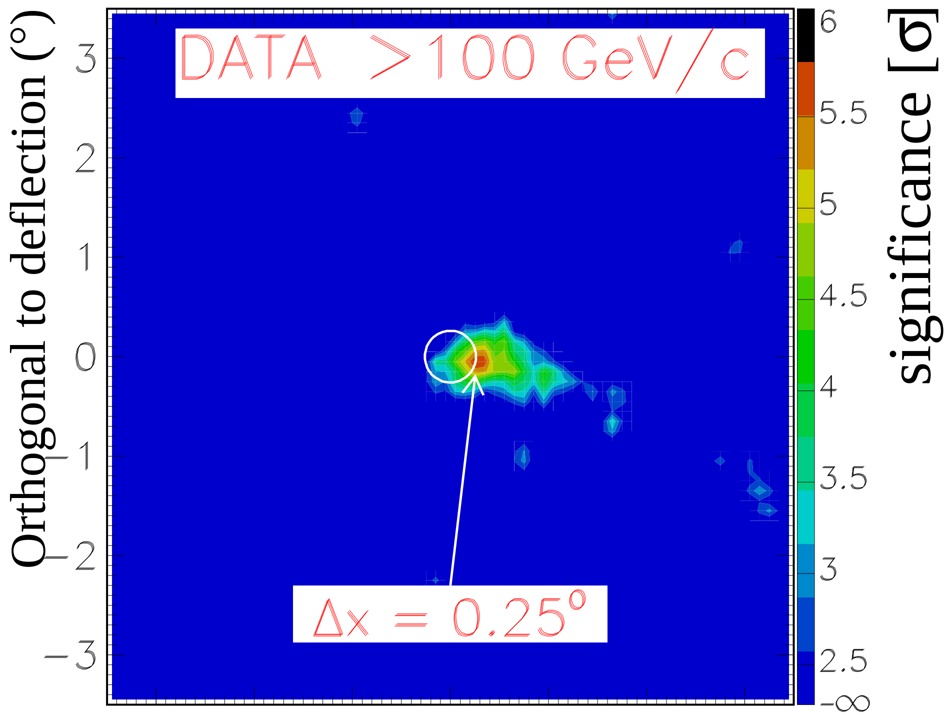
Observation of the Moon Shadow

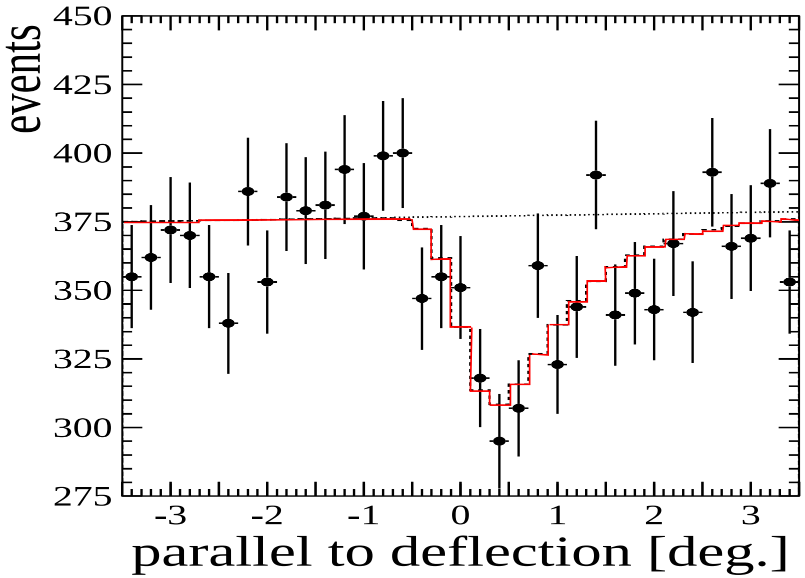
- analysis of two muon momentum ranges:
  p=65-100 GeV and p>100 GeV

- 9.4 σ event deficit

- simulation:
  - 75% Proton, 25% Helium
  - magnetic field model (IGRF)
  - angular resolution

- no 'anti shadow' observed





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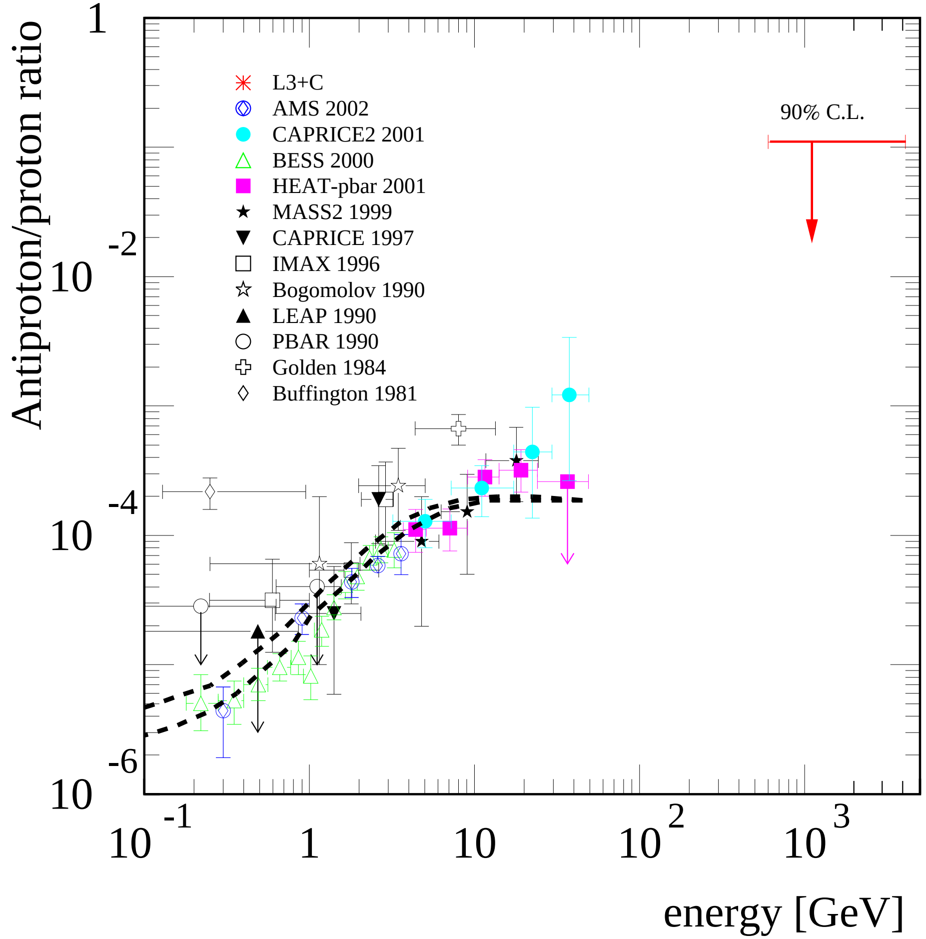
$\rightarrow$limit at 90% C.L.

$$\Phi(\bar{p})/\Phi(p) < 0.11$$

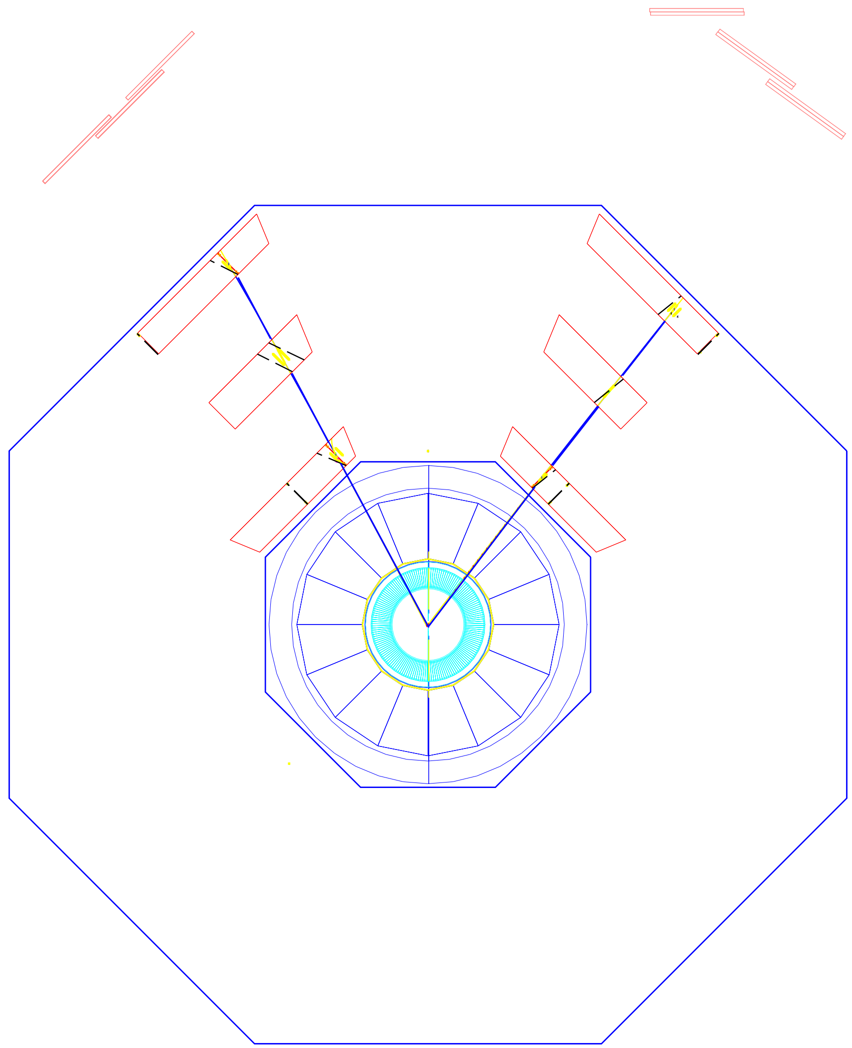


Outlook: Search for Exotic Events

decay of exotic particles

- motivation: e.g. Kolar Gold Mine
  Field events

- signature: two or three prong decay



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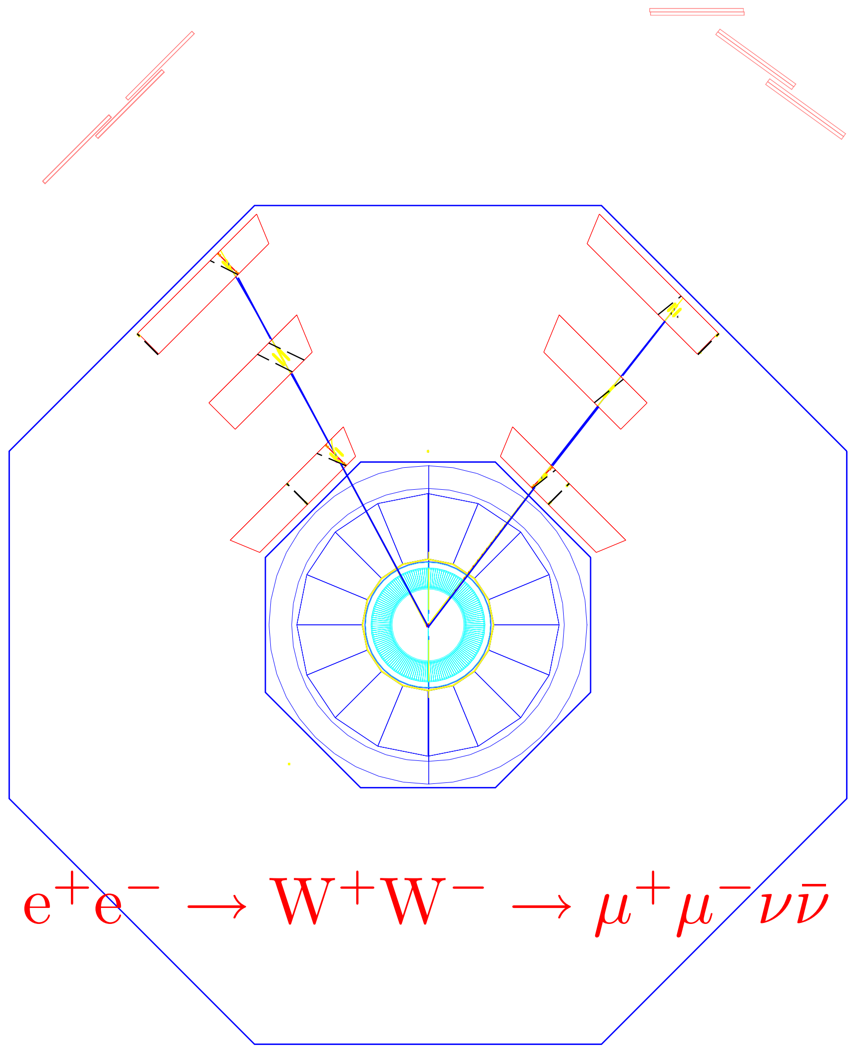

$$e^+e^- \rightarrow W^+W^- \rightarrow \mu^+\mu^-\nu\bar{\nu}$$

Outlook: Search for Exotic Events

decay of exotic particles

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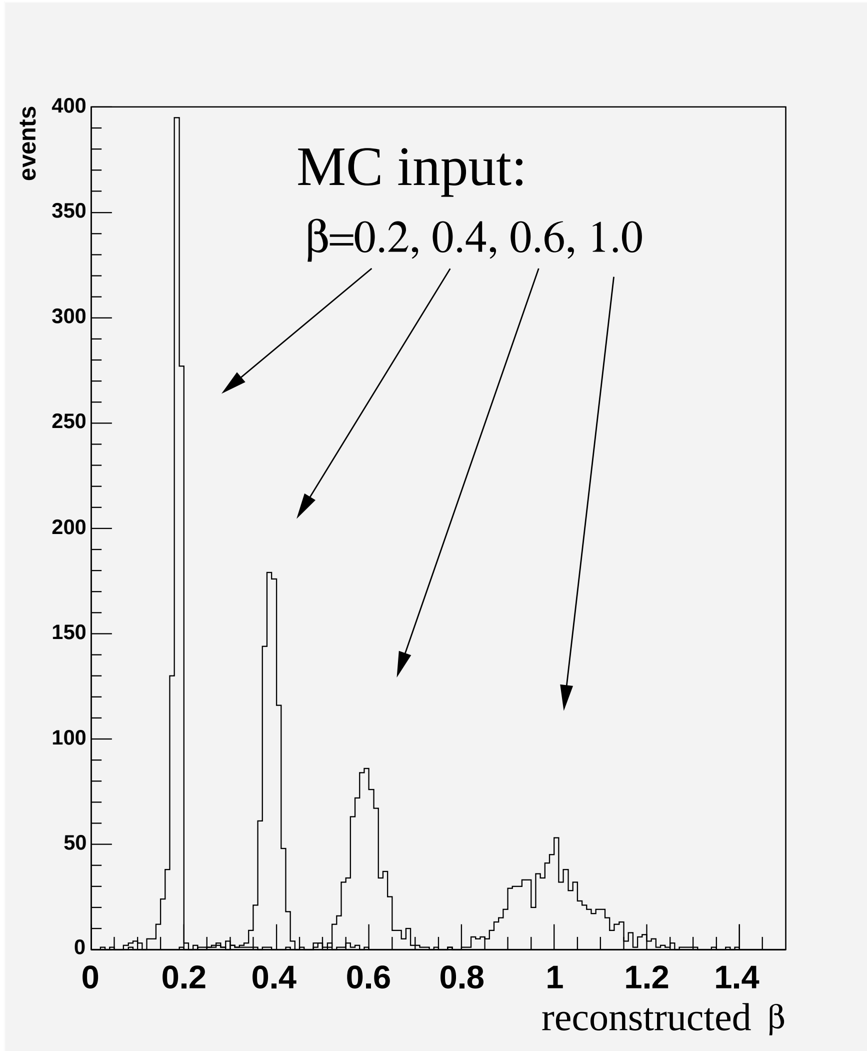
- signature: two or three prong decay

exotic low velocity particles

- motivation: e.g. AMS event
  Z/A=0.144

- velocity β from ToF in muon chambers $\rightarrow$Z/A



Outlook: Muon Bundles

Heitlers' model, superposition:

$$N_\mu \propto A \cdot (E_0/A)^\alpha$$
$$(\alpha \approx 0.9)$$

→sensitivity to primary composition

L3+C program:

- Rate of multiple muon events as fct. of multiplicity
- Momentum spectra of muons in multiple muon events
- above items as a fct. of shower size estimated in the L3+C air shower detector